

NEBRASKA DEPARTMENT OF ROADS
NDR STANDARD METHOD T 205

**DENSITY OF SOIL IN-PLACE BY THE
RUBBER-BALLOON METHOD**

Modifies

ASTM Designation: D 2167-66

SCOPE

- 1.1 This method covers the determination of the density in-place of compacted or firmly bonded soil using a rubber-balloon apparatus. The apparatus described in Section 3, however, is not suitable for very soft soil which will deform under slight pressure or in which the volume of the hole cannot be maintained at a constant value.
- 1.2 The following applies to all specified limits in this standard: For the purpose of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding-off method of AASHTO R 11, "Recommended Practice for Indicating Which Places of Figures are to be Considered Significant in Specified Limiting Values".

APPLICABLE DOCUMENTS

2.1 AASHTO Standards:

- T 180 "Moisture-Density Relations of Soils using a 10-lb. (4.54 kg) Rammer and an 18-in. (457 mm) Drop"
- M 231 "Weighing Devices used in the Testing of Materials"
- T 99 "Moisture-Density Relations of Soils using a 5.5-lb. Rammer and a 12-in. Drop"

APPARATUS

- 3.1 **Calibrated Vessel** - A calibrated vessel designed to contain a liquid within a relatively thin, flexible, elastic membrane (*rubber balloon*) for measuring the volume of the test hole under the conditions of this method (See Figure 1). The apparatus shall be equipped so that an externally controlled pressure or partial vacuum can be applied to the contained liquid. It shall be of such weight and size that it will not cause distortion of the excavated test hole and adjacent test area during the performance of the test. Provision shall be made for placing weights (*surcharge*) on the apparatus. There shall be a volume indicator for determining to the nearest 6.0 cc any change in volume of the test hole. The flexible membrane shall be of such size and shape as to fill the test hole completely without wrinkles or folds when

inflated within the test hole, and its strength shall be sufficient to withstand such pressure as is necessary to ensure complete filling of the test hole.

NOTE: *The description and requirements given in 3.1 are intended to be nonrestrictive. Any apparatus using a flexible (rubber) membrane and liquid that can be used to measure the volume of a test hole in soil under the conditions of this method to an accuracy within 1.0 percent is satisfactory.*

- 3.2 **Balances** - Balances conforming to the requirements of AASHTO M 231, Classes G 20 and G 2.

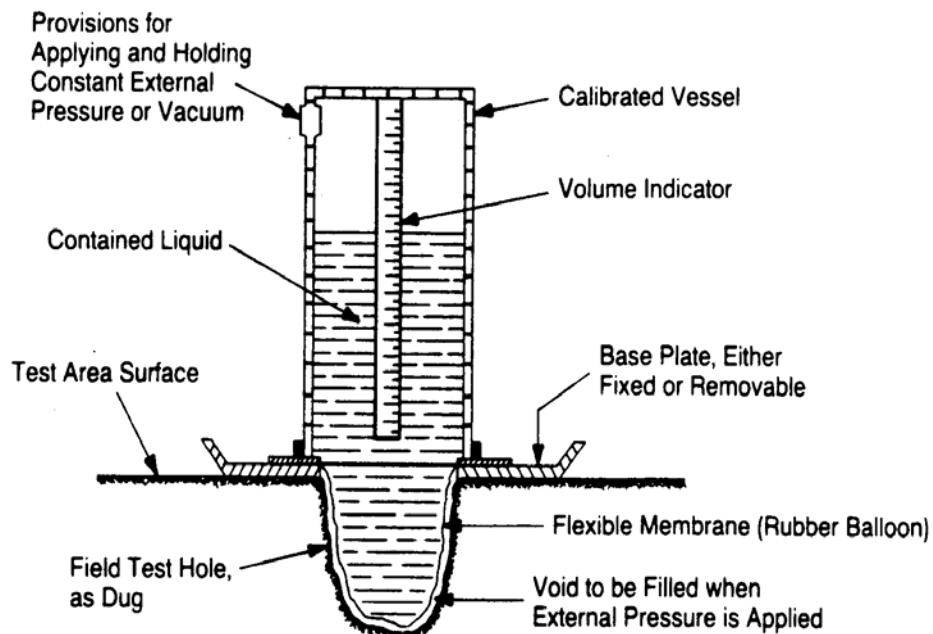


Figure 1 – Schematic Drawing of Calibrated Vessel Indicating Principle

- 3.3 **Drying Apparatus** - A stove, oven, or other apparatus proven suitable for drying soil or moisture samples.
- 3.4 **Miscellaneous Equipment** - Small pick, chisels, or spoons for digging test holes; plastic bags, buckets with lids, or other suitable metal containers that can be closed for retaining the soil taken from the test holes; thermometer for determining temperature of water; small paint brush.

CALIBRATION CHECK OF VOLUME INDICATOR

- 4.1 Verify the procedure to be used and the accuracy of the volume indicator by using the apparatus to measure containers or molds of determinable volume that dimensionally simulate test holes that will be used in the field. The apparatus and procedure shall be such that these volumes will be measured to within 1.0 percent. Containers of different volumes shall be used so that the calibration of the volume indicator covers the range of anticipated test hole sizes.

NOTE: The 4 and 6 inch molds described in AASHTO T 180 and in NDR T 99, or other molds prepared to simulate actual test holes may be used. Where several sets of apparatus are used, it may be desirable to cast duplicates of actual test holes. These sets should represent the range of sizes and irregularities in the walls of test holes that will be encountered. These fabricated holes can be used as standards for the calibration check of the volume indicator. This can be accomplished by forming plaster of Paris negatives in the test holes and using these as forms for portland cement concrete castings. After removing the plaster of Paris negative from the concrete casting, the inside surface of the fabricated holes should be sealed watertight and their volume determined as indicated in Section 4.

- 4.1.1 **Volumes of Containers** - Determine the mass of water, in grams, required to fill one of the containers. Slide a glass plate carefully over the top surface of the container in such a manner as to ensure that the container is filled completely with water. Determine the temperature of the water in the container. A thin film of cup grease smeared on the top surface of the container will make a watertight joint between the glass plate and the top of the container. Compute the volume of the container in cubic centimeters.

NOTE: Compute the volume of the container in cubic centimeters. This is done by multiplying the weight of the water, in grams, used to fill the container by the unit volume of water, in milliliters per gram, at the observed temperature, taken from Table I. Repeat this procedure until three values are secured for the volume of the container having a maximum range of variation of 2.8 cubic centimeters. (Since one milliliter is equal to 1.000027 cc and one gram of water at approximately 20 C (68 F) occupies a volume of 1.00177 cc, within the limits of accuracy of the equipment used, these units can be assumed to be equal and for the purpose of computation can be used interchangeably.)

- 4.1.2 **Calibration Check Test** - Place the rubber-balloon apparatus on a relatively smooth horizontal surface and take an initial reading on the volume indicator. Transfer the apparatus to one of the containers and take the reading on the volume indicator when the rubber balloon completely fills the container. Apply pressure to the liquid in the apparatus until there is no change indicated on the volume indicator. Note and define, in repeatable terms, the pressure applied. It will usually be necessary to add mass (surcharge) or other force to the apparatus to prevent it from rising. Note and record the total amount of mass or define, in repeatable terms, the force added. The difference between the initial and final readings of the volume indicator is the indicator volume value for the container. The membrane may be withdrawn from the container by applying a partial vacuum to the liquid in the apparatus. Repeat the procedure for the other containers.

NOTE: If the calibration container or mold is airtight, it may be necessary to provide an air escape, since the rubber membrane can entrap air within the container and cause an erroneous volume measurement. After the volume of the container has been determined with water and prior to the insertion of the rubber balloon, small air escape-holes may be provided by placing lengths of small-diameter string over the edge of the container and down the inside wall slightly beyond the bottom center. This will permit air

leakage during the filling of the container with the membrane. If such a procedure is necessary in the laboratory, it may be necessary to use a similar procedure on tightly bonded soil in the field.

Before any measurements are made, it may be necessary to distend the rubber balloon and remove air bubbles adhering to the inside of the membrane by kneading.

In field tests, the additional weights (surcharge) will increase the stress in the unsupported soil surrounding the test hole and will tend to cause it to deform. The stress may be reduced by using a base plate.

TABLE I
Volume of Water Per Gram Based on Temperature^a

Temperature		Volume of Water, ml per g
Centigrade	Fahrenheit	
12	53.6	1.00048
14	57.2	1.00073
16	60.8	1.00103
18	64.4	1.00138
20	68.0	1.00177
22	71.6	1.00221
24	75.2	1.00268
26	78.8	1.00320
28	82.4	1.00375
30	86.0	1.00435
32	89.6	1.00497

^a values other than shown may be obtained by referring to Handbook of Chemistry and Physics, Chemical Rubber Publishing Co., Cleveland, Ohio.

PROCEDURE - Refer to Figure 2

- 5.1 Prepare the surface of the test hole site so that it is reasonably plane. Set the apparatus on the test hole site and take an initial reading on the volume indicator of the calibrated vessel using the same pressure on the liquid in the vessel and the same amount of surcharge weight as was used in the calibration check. After taking this initial reading on the volume indicator, scribe the outline of the apparatus on the test hole site. Make notes of the pressure used, record the amount of the surcharge and the initial volume reading. If the apparatus was calibrated with a base plate, the base plate shall remain in place throughout the field test.
- 5.2 Remove the apparatus from the test hole site and dig a hole centered within the outline scribed for the apparatus. Exercise care in digging the test hole so that soil around the top edge of the hole is not disturbed. Place all the soil removed from the test hole in an airtight container for mass and moisture content determinations. The test hole shall be of the minimum volume shown in Table II. Larger holes will provide improved accuracy and shall be used when practicable. The dimensions of the test

hole are related to the apparatus design and the pressure used. In general, the dimensions shall approximate those used in the calibration check procedure.

- 5.3 After the test hole has been dug, place the apparatus over the test hole in the same position used for the initial reading and inflate the flexible membrane in the hole. Apply the same surcharge mass and pressure on the liquid in the vessel as used and recorded during the calibration check procedure. Take and record the reading on the volume indicator. The difference between this reading and the initial reading obtained in 5.1 is the volume of the test hole.

NOTE: Attention is called to instances in weak soils where the pressure applied to the liquid in the vessel can deform the test hole to such an extent as to give an erroneous volume. In such instances, the apparatus shall be modified and recalibrated using less surcharge weight and pressure on the liquid in the vessel, or it may be necessary to resort to another method.

TABLE II
Minimum Field Test Hole Volumes
and Minimum Moisture Content Samples
Based on Maximum Size of Particle

Maximum Particle Size	Minimum Test Hole Volume, cc (a)	Minimum Moisture-Content Sample, g
No. 4 sieve	450 b	200
1/2 in.	600 b	500
3/4 in.	700 b	500
1 in.	750 b	1,000
2 in.	c	2,500
2 1/2 in.	c	2,500

- a. The type of rubber-balloon volume measures used by the Nebraska Department of Roads do not have the capacity for measuring volumes greater than approximately 900 cc, without rupturing the rubber membrane. Therefore, care should be taken that the volume of the hole is not larger than this.
 - b. If the thickness of the layer being tested is such that the minimum volume cannot be obtained, the volume of the test hole should represent the entire layer and may be smaller than the recommended size.
 - c. If in-place density tests are required in material having these gradations, another method shall be used to determine the volume.
- 5.4 Determine the weight of all the moist soil removed from the test hole, mix this material thoroughly, select a moisture-content sample in accordance with Table II, determine its wet weight, then dry it to substantially constant weight, and determine the dry weight. The drying temperature shall be such that the material is not overheated. Overheating may remove material other than moisture, causing an erroneous moisture reading.

CALCULATIONS

- 6.1 Calculate the moisture content, w (expressed as a percentage of the weight of the dry soil), of the soil as follows:

$$w = \frac{\text{weight of moisture}}{\text{weight of dry soil}} \times 100$$

- 6.2 Calculate the volume, wet and dry density of the soil as follows:

$$V = V_2 - V_1$$

$$DW = \frac{W}{V}$$

$$D = \frac{DW \times 100}{100 + w}$$

where:

V_1 = Volume measure initial reading, cubic centimeters

V_2 = Volume measure final reading, cubic centimeters

V = Volume of hole, cubic centimeters

W = Weight of wet soil taken from test hole, grams

DW = Wet density, g/cc

D = Dry density, g/cc

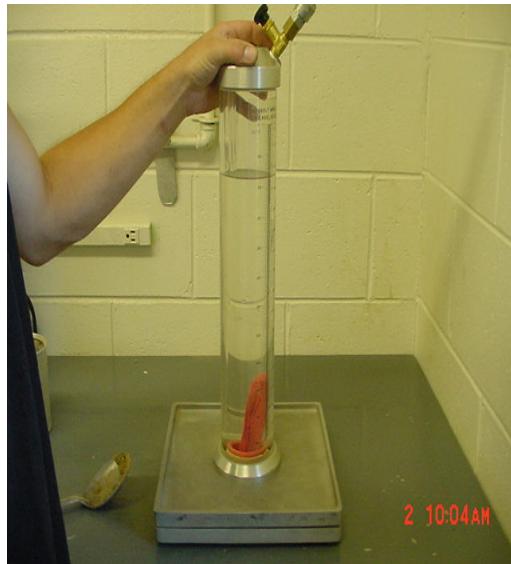
w = Moisture content of sample expressed as a percentage of the weight of the dry soil.

REPORT

- 7.1 The moisture content shall be reported to one decimal place. The dry density shall be reported in grams per cubic centimeter (g/cc.) to two decimal places.

Figure 2 – Volume Determination – Rubber Balloon Method

After initial reading has been taken, dig the density hole using the field density plate as a template.



Pumping the balloon into the density hole. Operator takes reading at lowest point on the graduated cylinder.

Replacing the actuator bulb in the quick coupler changing from a pressure operation to a vacuum operation, pump water and balloon back into the cylinder.

